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Abstract:

Dual Process Theory has recently been applied to Autism Spectrum Disorder (ASD) to suggest that reasoning by people with ASD and typically developing (TD) people with higher levels of ASD-like traits can be characterised by reduced intuitive and greater reflective processing. 26 adolescents and adults with ASD and 22 TD adolescents and adults completed the AQ, the cognitive reflections test (CRT) to measure intuitive and reflective reasoning and 12 items from Raven's Advanced Progressive Matrices. The ASD group produced less intuitive responses, and the degree of ASD-like traits showed a negative correlation with intuitive responses and positive correlation with reflective responses on the CRT. These results are consistent with ASD being associated with reduced intuitive reasoning and greater reflective reasoning.

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by persistent deficits in social communication and interaction combined with restricted, repetitive patterns of behaviour, interests, or activities (APA, 2013). Studies of prevalence rates of ASD report estimates of up to one in 68 children (CDC, 2015). Whilst ASD is defined in DSM-5 as a behavioural disorder, much research over the past 25 years has focused upon cognitive differences in ASD, including difficulties in mindreading or empathizing and enhanced processing of local details (e.g. Baron-Cohen, 2009; Baron-Cohen, Leslie & Frith, 1985; Frith & Happé, 1994; Mottron, Dawson, Soulières, Hubert, & Burack, 2006), which address social and non-social aspects behaviours characteristic of ASD, respectively. One promising area of recent research into the cognitive differences in ASD has involved reasoning. Reasoning and decision making are core human capabilities that enable effective participation within society (e.g. Irvin & Stansbury, 2004), yet to date these have received relatively little attention within the ASD field. Recently, however, Brosnan, Lewton and Ashwin (2016) have proposed a Dual Process Theory account of ASD. Dual Process Theory has been a major theory of reasoning within psychology for over 50 years (Frankish & Evans, 2009). It proposes that there are two distinct types of reasoning process: Type 1 which is autonomous and typically rapid and nonconscious ('intuition'), and Type 2 which is typically slower and conscious ('reflective') and dependent upon cognitive ability (see Evans 2011; Evans & Stanovich 2013; Kahneman 2011; Stanovich & West 2000, 2008; for reviews; see Keren & Schul 2009 for critique; see Kruglanski & Gigerenzer 2011 for an alternative view). As an example, Type 1 processing may result in getting a 'bad feeling' about someone when meeting them, despite not consciously knowing what led to that conclusion. Whereas Type 2 processing may result in someone not jumping to a conclusion about someone else until explicitly finding out more information about that person. Incongruent syllogisms provide a measureable example in which real-world context influences Type 1 processing (erroneously) whereas Type 2 processing results in a correct response (Evans, Barston, & Pollard, 1983). In the example "All flowers need water. Roses need water. Therefore, roses are flowers", despite the believability of the two premises, the conclusion does not follow logically.

Brosnan et al. (2016) applied this dominant model of reasoning to ASD, to suggest that reasoning in ASD can be characterised as more reflective (Type 2) than intuitive (Type 1) processing. This is consistent with other research that has identified more logically consistent, circumspect reasoning within ASD as well as deficient intuition and difficulty making rapid decisions (Brosnan, Chapman & Ashwin, 2014; De Martino, Harrison, Knafo, Bird & Dolan, 2008; Klin & Volkmar, 1997; Luke, Clare, Ring, Redley, & Watson, 2012; Shah, Catmur & Bird, 2016). For example, De Martino et al. and Shah et al. have identified that autistic participants are less susceptible to biases such as the classic framing effect (Tversky & Kahneman, 1981) associated with Type 1 processing. This lack of bias resulted in 'enhanced logical consistency' reflecting Type 2 processing in the autistic group. Within the general population, higher levels of ASD-like traits (measured via the AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) were also associated with reduced intuitive and greater reflective processing (Brosnan et al., 2016).

One of the most widely used behavioural assessments of intuition and reflection is the Cognitive Reflections Test (CRT; Frederick 2005). The CRT comprises of three reasoning questions that have both an intuitive (incorrect) and reflective (correct) response (see Method section). Within Dual Process Theory, an initial intuitive response is theorised to reflect the output from Type 1 processing which has not been over-ridden by reflective (Type 2) processing. The over-riding of initial intuitive reasoning by subsequent reflective reasoning is demonstrated by achieving the correct answer. The typical dominance of the intuitive response in this task is reflected in over 80% of more than three thousand American college students exhibiting reasoning biased away from Type 2 processing (Frederick, 2005). Despite the relatively simple mathematics involved, most students do not get any questions correct, and less than 10% get all three questions correct (Toplak, West & Stanovich, 2011). Brosnan, Hollinworth, Antoniadou and Lewton (2014) also report a sex difference with females more likely than males to provide an intuitive response, and vice versa (see also Campitelli &

Gerrans, 2014). Whilst intuitive and reflective responses are yoked such that if one is provided the other cannot be provided, it is also possible to make random errors.

Within Dual Process Theory, reflective, but not intuitive, reasoning is dependent upon general cognitive ability. Brosnan et al., however, did not take an index of general cognitive ability in addition to the CRT. Therefore, it could be that general cognitive ability may have played a role in the findings of differences in reasoning in ASD compared to typically developing participants (TDs). Within a TD university student-based population, higher AQ scores have been found to positively correlate with Raven's Advanced Progressive Matrices (Fugard, Stewart & Stenning, 2011). The present study therefore sought to replicate the CRT reasoning task on an ASD sample while including an index of general cognitive ability, 12 Ravens Advanced Progressive Matrices, in order to identify if more intuitive responding is related to generally lower levels of general cognitive ability in ASD (and reflective responding by higher levels of general cognitive ability). This is important as using the CRT assessment as an index of intuitive processing relies on incorrect responses. It was expected that the ASD group would show reduced intuitive reasoning and greater reflective reasoning compared to TDs. When looking at ASD-like traits in the combined samples, it was expected that higher ASD-like traits would be related to fewer intuitive and greater reflective responses on the CRT.

Method

Participants

The participants comprised 26 individuals with ASD (17 male, 11 female) and 22 typically developing participants without ASD (11 male, 11 female) who served as the TD group. The ASD group had a mean age of 18.3 years (range 16-21; s.d. = 2.22) and the TD group had a mean age of 17.9 years (range 17-18; s.d. = 2.90). The proportion of males and females did not significantly differ between the two groups ($\chi^2(1) = .33$, ns).

The ASD Group comprised of participants attending a University Summer School for students on the autism spectrum focused on providing an insight into university life ($N = 18$). On application to the summer school, students provided evidence of clinical diagnosis of ASD using international criteria (DSM-IV, APA, 1994; ICD-10, WHO, 1992) by a qualified professional to establish diagnosis. Further measures were employed to index the degree of ASD-like traits. The Social Communication Questionnaire (SCQ-Lifetime; Rutter, Bailey, & Lord, 2003), a 40-item parent report measure and the Autism Spectrum Quotient, a 50-item self-report measure (AQ: Baron-Cohen et al., 2001). The mean scores on the SCQ measures for the group were significantly above the clinical cut-offs (Mean SCQ score = 16.35, s.d. = 3.02, range = 13-27; $t(17) = 3.79$, $p = .002$). The mean score on the AQ for the ASD group was 29.42, which is considered reflective of clinical levels of ASD (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005; see Ruzich et al., 2015).

The remaining eight participants were recruited from the Student Disability Service at the University of XXXX. An email advertising the study was sent to the service actively recruiting people with a formal diagnosis of ASD for a study on reasoning. Although the diagnostic reports had been confirmed by the Student Disability Service, they were not available to the researchers. Scores on the SCQ were not available for this subset of participants. All participants from this group attained a score on the AQ of at least 26 (Woodbury-Smith et al., 2005). The typically developing (TD) group ($N = 22$) was an opportunity sample of male and female students commencing their first year at the same University. Inclusion in the TD group was by confirming that they had never received a clinical diagnosis of an Autism Spectrum Disorder or any psychiatric conditions and their scores on the AQ. The research was approved by the Psychology Departmental Research Ethics Committee at the University of XXXX, which implements the ethical guidelines of the British Psychological Society.

Measures

The Cognitive Reflection Task (CRT; Frederick, 2005) is a widely used 3-item performance measure of intuition and reflection. Each question has a potentially intuitive and reflective answer, as well as the potential for wrong answers. Scores can therefore range from 0 to 3 for each subscale. (Note: the intuitive response is a wrong answer). The questions were (as Frederick, 2005, except 'pence' adjusted from 'cents', and £/pound for \$/dollar): (1) A bat and a ball cost £1.10 in total. The bat costs a pound more than the ball. How much does the ball cost? ____ pence [Correct answer 5 pence; intuitive answer 10 pence]; (2) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? ____ minutes [Correct answer 5 minutes; intuitive answer 100 minutes]; (3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ____ days [Correct answer 47 days; intuitive answer 24 days]. The CRT a reported Cronbach's alpha of 0.66 (Campitelli & Gerrans, 2014).

The Raven's Advanced Progressive Matrices (SET I) was included as an index of general cognitive ability (see Chiesi, Primi, & Morsanyi, 2011; Chiesi, Ciancaleoni, Galli, & Primi, 2012; Ciancaleoni, Primi, & Chiesi, 2010; Donati et al., 2014; Morsanyi et al., 2012; Primi et al., 2015; see also Waschl et al., 2015). Set I of the Advanced Progressive Matrices (APM; Raven, 1962) was administered as a short form of the Raven's Standard Progressive Matrices. Set I consists of 12 matrices, and participants select the correct response out of eight possible responses. Set I is usually used as a practice and screening set for the full test, and it draws on all the intellectual processes sampled on the full test (although does not extend to the highest levels of complexity). This measure has adequate validity and reliability and a reported Cronbach's alpha of .78 (see Chiesi et al., 2011; 2012).

Results

Table 1 about here

The means (standard deviations) for both groups are reported in Table 1. A MANOVA was conducted with CRT-Intuitive and CRT-Reflective responses as the dependent variables and Group (ASD/TD) as the independent variable with sex (Male/Female) and general cognitive ability as covariates. The ASD group made significantly less intuitive responses than the TD group ($F(1,44)=4.43, p<.05$), with no significant difference in reflective responses ($F(1,44)=2.38, p>.05$). The covariates were not significant ($P>.05$). Finally partial correlations were run pooling all the participants together for greater power and controlling for group (ASD/TD) and sex (Male/female), and this revealed a significant negative correlation between ASD-like traits and CRT-Intuitive ($r(44)= -0.29, p<.05$), and a significant positive correlation between ASD-like traits and CRT-Reflective ($r(44)= 0.25, p<.05$). Repeating these partial correlations, CRT-Intuitive and CRT-Reflective did not significantly correlate with the index of general cognitive ability (both $p>.05$)

Discussion

Consistent with the Dual Process Theory of ASD (Brosnan et al., 2016), the ASD group had fewer intuitive responses on the CRT, though no group differences were found for reflective reasoning. The samples were then pooled to increase the power in looking at the relationship of ASD-like traits with reasoning, and results with the pooled sample showed that higher ASD-like traits related to fewer intuitive reasoning responses and more reflective responses on the CRT. The results were not related to general cognitive ability as the groups were comparable in their level of general cognitive ability and this was controlled for in the analysis of the group differences. Furthermore, no relationship was found between general cognitive ability and intuitive or deliberative reasoning. This

is pertinent as intuitive responses on the CRT are incorrect responses, and the inclusion of the general cognitive ability measure is consistent with the ASD sample not simply making more errors *per se*, but being less susceptible to biases in reasoning specifically (Brosnan et al., 2016; De Martino et al., 2008; Shah et al., 2016). Inconsistent with previous research, the ASD sample did not obtain more correct answers than the TD group. Together, however, the results generally support the Dual Process Theory of ASD (Brosnan et al., 2016) in ASD and TD samples containing comparable numbers of males and females.

There are few behavioural measures available to test intuition, and the CRT-intuitive index is heavily dependent upon the CRT-Reflective index, which is based upon getting answers incorrect (albeit in a pre-specified way, as opposed to random errors). Pennycook et al. (2015) argue that the CRT-Intuitive index is best viewed as a propensity towards intuition, rather than intuitive ability.

Consistent with this, the present study suggests that those with ASD do not have such a propensity towards intuitive (Type 1) processing as is typically seen in the general population, rather they have a propensity towards reflective (Type 2) processing. Partial correlations (controlling for group and sex) indicated that higher levels of ASD-like traits significantly influence this propensity towards reflective processing and away from intuitive processing. The ASD group, however, did not obtain more correct responses, and it is conceivable that ASD is associated with a reflective propensity rather than a reflective ability. That is to say, those with ASD may be characterised as more likely to engage in reflective processing, but not necessarily that the reflective processing will result in the correct response (correct responses may be more to related general cognitive ability – this relationship was not found in the present study but has been reported by Toplak et al., 2011). Toplak et al. (2011) suggest that whilst reflective processing on the CRT and general cognitive ability are correlated with each other and performance on other reasoning tasks, the CRT additionally and uniquely assesses the tendency towards over-riding intuitive processing with reflective processing. Morsanyi, Handley and Evans (2010) also found that those with ASD were less biased in their reasoning (less susceptible to the conjunction fallacy) consistent with reduced Type 1 processing, but

they were not more logical than the TD group in a normative sense. The current results are consistent with those findings, as we also found that the ASD group had reduced intuitive reasoning compared to the TD group, but that group differences were not evident for reflective reasoning. Whether intuitive processing is impaired in ASD or intact but dominated by reflective processing is still unknown (Brosnan et al., 2016).

Intuitive processing is associated with using heuristics and biases which prove useful in some instances, but can also result in errors of judgement in other situations. This indicates that the reasoning of people with ASD will be less susceptible to potentially erroneous biases (Brosnan et al., 2016; De Martino et al., 2008; Shah et al., 2016). Since many social and emotional processes are typically associated with intuitive processing because they involve rapidly-changing situations requiring fast judgements and responses (see Rand, 2016; Rand et al., 2012; 2014), a bias away from intuitive processing would be expected to result in social difficulties consistent with those seen in ASD. For example, when recounting a story someone might perceive quick and subtle cues of boredom in others, and so intuitively alter the story to suit the audience's mood, either by making it more interesting or ending it quickly. If someone with ASD noticed the same cues while recounting a story they might not intuitively make such a fast and automatic alteration the story, and instead try and use reflective mechanisms which would prove difficult and effortful given that cognitive resources were being used to tell the story (which might even lead to an even longer and more laborious story). In this example, social communication and interaction difficulties in ASD are related to difficulties processing social heuristics typical of intuitive (Type 1) processing. Returning to the example in the Introduction, Type 1 processing quickly resulting in a 'bad feeling' about someone else, may lead to consequent behaviours that minimise the risk of being bullied, exploited or harmed. In this situation, Type 2 processing might be less likely to quickly detect this 'bad feeling', resulting in greater vulnerability to being bullied, exploited or harmed.

In addition to a relative weakness in mindreading and empathizing, Baron-Cohen (2006; 2009; Baron-Cohen et al., 1985; 2009) characterises ASD as a relative strength in systemizing, which is defined as a drive to analyse or construct systems. What defines a system is that it follows rules, systemizing is the identification of the rules that govern the system, in order to predict how that system will behave. Both self-report and behavioural assessments of systemizing have been found to correlate with self-report and behavioural assessments of Type 2 processing (Brosnan et al., 2014b). An overreliance of systemising (or hyper-systemising) may therefore be related to a relative dominance of Type 2 processing in ASD. Brosnan et al. (2014b) also found that self-report and behavioural assessments of empathizing correlated with self-report and behavioural assessments of Type 1 processing. Thus reduced empathizing and preserved or enhanced systemising would be seen as correlates of relatively reduced Type 1 processing relative to Type 2 processing within a Dual Process Theory of ASD. For example, the Dual Process Theory of ASD would propose that ASD is characterised by difficulties processing rapid social heuristics, such as low intensity facial emotion expressions (e.g. Wingenbach, Ashwin & Brosnan, 2017), rather than a deficit in empathy (although there may be downstream consequences for empathy of impaired facial emotion recognition capabilities; e.g. Clark, Winkielman, & McIntosh, 2008). The extent to which Type 2 processing is employed by autistic people in tasks that typically employ Type 1 processing is also an avenue for future research, for example, explicit strategies for facial emotion recognition ('corners of mouth turned down, lowered eyebrows = sad': Rutherford & MacIntosh, 2007; Walsh, Vida, & Rutherford 2014; see also Ashwin et al., 2007; Brosnan et al., 2015; Golan and Baron-Cohen, 2006; Golan et al., 2010).

Future research can also establish whether a bias away from Type 1, intuitive processing is related to a bias away from utilising context in perceptual and cognitive tasks. Evans and Stanovich (2013) identify contextualised processing as a typical correlate of Type 1 processing. Decontextualised abstract reasoning is typical of Type 2 processing, although this is not a defining feature as not all Type 2 processing is context-free. Within the Reverse Hierarchy Theory of visual perception, an

initial rapid processing of low spatial frequency information for gist (vision at a glance) is proposed to precede a slower detailed processing of high spatial frequency (vision with scrutiny; see Vanmarcke & Wagemans, 2016). Vanmarcke and Wagemans found that higher autistic traits (within a general population) were associated with more effective processing of high spatial frequency (fine, detailed analysis) in conditions with more time. ASD was found to be associated with deficits in the rapid processing of social relations specifically from visual scenes (Vanmarcke et al., 2016a;b). Future research can establish whether Type 1 and 2 processing within the context of reasoning relate to these differences in rapid visual perception and categorisation of real-life scenes as well as established differences in perceptual and cognitive assessments of global, gist, or gestalt processing (e.g. Bowler, Gaigg & Gardiner, 2008; Farran & Brosnan, 2011; Shah & Frith, 1983; 1993; Parra et al., 2016), which inform Weak Central Coherence Theory, Enhanced Perceptual Theory and the Task Support Hypothesis (Frith & Happé, 1994; Mottron, et al., 2006; Bowler, Matthews, & Gardiner, 1997; respectively). Whilst Brosnan et al. (2016) showed the same pattern of Type1/ Type 2 processing in an ASD sample and a TD sample with high autistic traits, this does not necessarily imply that ASD is an extreme variant of autistic traits and that research based upon high autistic traits groups will necessarily extend to autistic groups.

There are some limitations to the study to be noted. One limitation is the nature of the sample, as the participants all had higher levels of general cognitive ability as they were either going to university or intending to go to university, and therefore are not reflective of the ASD population as a whole. Further research of this type needs to be undertaken with people with ASD of varying levels of general cognitive ability. There was a significant age difference between the groups, although the means were just above and just below 18 years of age (adding in age to the MANOVA, makes no discernible difference to the result). Although no participants self-reported a comorbid disorder, this was not formally screened for through questionnaire assessments in the present study. Whilst there was a relatively large proportion of females within the ASD sample, numbers were not sufficient to allow for a detailed analysis of sex differences. In addition, the CRT and Set I of the Advanced

Progressive Matrices assessments have limited numbers of questions, so the results need to be replicated with further measures. We also did not include a measure of verbal ability. Despite these limitations, the findings are largely consistent with the Dual Process Theory account of ASD. In summary, the present study replicates previous results consistent with the Dual Process Theory of ASD, showing that greater ASD-like traits are associated with reduced intuitive reasoning and greater reflective reasoning and ASD is associated with diminished intuition. Furthermore, this is the first study to identify that more intuitive responding is not solely due to lower levels of general cognitive ability in ASD. This is important as using the CRT assessment as an index of intuitive processing relies on incorrect responses.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Table 1. Means (standard deviations) for the ASD and TD groups

Demographics	ASD	TD	Cohen's d	
And measures	N= 26	N=22		
Age	18.65 (1.85)	17.91 (0.29)	0.55	t(46)=2.01, p<.05
AQ (max 50)	29.42 (5.48)	14.73 (4.91)	2.82	t(46)=9.71, p<.001
APM (max 12)	9.58 (1.72)	9.91 (1.44)	0.21	ns
CRT-Intuitive (max 3)	0.54 (0.71)	1.14 (1.04)	0.67	t(46)=2.36, p<.05
CRT-Reflective (max 3)	1.38 (0.85)	1.82 (1.10)	0.45	ns

Note: AQ – Autism Quotient; APM – Advanced, Progressive Matrices (Set I); CRT – Cognitive

Reflections Test.